International Council for the Exploration of the Sea

CM 1996/S:14

DOES BLUE WHITING MIGRATE FROM PORCUPINE BANK TO BAY OF BISCAY AFTER SPAWNING SEASON?

By

Carrera, P.(1); Meixide, M.(2); Porteiro, C(2). And Miquel, J.(3)

(1) Instituto Español de Oceanografia. Apartado 130, 15080 A Coruña (Spain)
(1) Instituto Español de Oceanografia. Apartado 1552, 36280 Vigo (Spain)
(1) Instituto Español de Oceanografia. Apartado 291, 07080 Palma de Mallorca (Spain)

ABSTRACT

During March-April 1994 and 1996 two cruises have been carried out around Bay of Biscay in order to check movements of blue whiting using acoustic methods. These cruises consisted in a double coverage of an area from 47°30' N, 7°15' W to 43°30' N, 6°30' W along the French and Spanish continental shelf-break (200m to 1000 m isobaths). Whereas in 1994 a zigzag survey design with 20 nmi between peaks was performed, in 1996 the survey design consisted in parallel transepts with 24 nmi apart and, in both cases, normal to depth contour.

The majority of the blue whiting from the Northern areas migrates to the main spawning area which is located West of British Isles, mainly around Porcupine Bank, during March-April. After spawning, there is an exodus from this area to the feeding grounds. The main migration route is in Northward direction which has been widely reported but it is not known if fish coming from the Bay of Biscay takes part in this migration. From this surveys, it could be concluded that there are important movements of blue whiting around Bay of Biscay, mainly on younger fish, and these seem to be in relation with a southward migration after spawning.

INTRODUCTION

Blue whiting (*Micromesistius poutassou*, Risso) is an important fish species in terms of its abundance in the North Atlantic. It has a widespread distribution along the continental slope in the North Atlantic and also in the Mediterranean sea. Contrary to the normal behaviour of other gadoids, blue whiting is not a typical demersal specie, and spends the major part of its life with no noticeable relationship with the sea bottom (Zilanov, 1980). This has enabled this especies to be studied by means of acoustic methods since 1972 (Anon, 1982). One of the most important features of this species is its ability to migrate from feeding areas to spawning ones and viceversa. These movements in the North Atlantic are well documented (Zilanov, 1980, Anon, 1982, Bailey, 1982, Anon, 1993a) and different acoustic survey have been carried out, especially in March/April around the west of the British Isles where the major spawning stock is congregated over a relatively small area; after spawning, there is a rapid migration towards feeding areas.

In the southern part of the distribution area, not one attempt had been performed before to demonstrate the movements of the blue whiting. Under the AIR project SEFOS (*Shelf Edge and Oceanographic Studies*), whose main objective is the study of the relationship between the distributions and migrations of commercially important fish and the hydrography of the shelf edge, the Instituto Español de Oceanografia programmed two acoustic surveys in 1994 and in 1996 to study the movements of blue whiting around the Bay of Biscay.

Before this, in a meeting held in Vigo, the Spanish acoustic surveys carried out in 1991-93 were analysed. These surveys had a zigzag track with 10-12 miles between peaks, from 20 m isobath to 1 000 m isobath. The blue whiting distribution in each survey was studied by means of geostatistical techniques using the integration values for each transect as unit sampling. The losses in precision are negligible when the distance between peaks increases to a maximum of 20 miles; this analysis was carried out by performing an experimental variogram with the three cruises combined and testing the confidence intervals as a percentage of the mean, when transects were eliminated both systematically and randomly.

Finally, the survey were designed covering the shelf-edge (between 200m and 1 000m) where blue whiting are mainly distributed (Meixide et al, 1991). In order to check movements, the area should be covered twice.

MATERIAL AND METHODS

The surveys were carried out on board R/V "Cornide de Saavedra". The acoustic trips were performed over the Bay of Biscay (VIIIa,b,c ICES Divisions). Table I summarises the main features of these trips. Surveys design were in both cases normal to the depth contours, from 200 m to 1000 isobath (figure 1). Besides, in 1996 in the Spanish area during the first trip, transects were extended to 20 m and extra transects were also allocated in order to evaluate the Spanish fraction of sardine stock, but for this analysis this transects were not used.

A Simrad EK-500 echosounder-echointegrator with a 38kHz split beam transducer was used. In 1994 results of the calibration performed in November 1993 were assumed whereas in 1996 the equipment was calibrated before the survey according to Foote *et al* (1987). Surveys were conducted day and night at a ship speed of 10 knots. Acoustic back-scatterings (S_a values, expressed as m^2/nmi^2, Bodholt, 1990) were directly collected every nautical mile (nmi) and stored in a PC, which controlled the main settings of the echosounder. Geographical position was also taken by GPS.

Biological samples were obtained in pelagic trawl stations to identify blue whiting and its age structure. In each trawl station a random sample of 80 fish was sampled (length, weight, sex, maturity and otolith) and 40 were aged on board. This random sampling strategy was adopted in order to obtain unbiased parameters (Anon 1994) and to make the examination of age structure easier during the cruise.

Changes in acoustic back-scatterings of blue whiting were studied by means of geostatistics tools. The use of geostatistical techniques (Matheron 1971) and their applications in fisheries research, both for mapping and variance estimates, is well documented in Conan (1985) and Petitgas (1991, 1993) and has been recommended as a tool for the analysis of acoustic survey data in Anon (1993b). The analysis was performed applying the transitive theory on the transect cumulated data. Besides another estimation of the variance of the abundance estimate was undertook using the intrinsic theory on the S_a values assigned for blue whiting in each nmi. These analysis were performed using EVA v1.0 (Petitgas and Prampart, 1993) and SURFER v6.0 (Golden Software, Inc.) packages.

In order to avoid problems with the geometry of the habitat in these analysis, the surveyed area was firstly divided in three zones as follows:

North France: from the upper surveyed limit to 45°N

South France: from 45° N to the Spanish-French border

Spain: from the Spanish-French border to 6°15'W

These main areas were chosen due to the different direction of the continental shelf-break (225° degrees aprox. in North France, 0° in South France and 90° in Spain), where blue whiting is mainly concentrated.

Mean S_a values of each zone and the surface of the blue whiting distribution area were used to estimate the abundance according to Nakken and Dommasnes (1975). The following TS/Length relationship (Anon, 1982) was used:

$$TS = 21.8 * \log(L) - 72.8 \text{ (dB)}$$

Changes in population age structure as well as maturity stages using a key of six empirical stages (Abaunza *et al*, 1995) were also checked.

RESULTS

A total of 811 and 762 nmi respectively were surveyed in 1994. In 1996, 640 nmi were surveyed during the first trip and 580 nmi during the second. Fig. 2a and b show a proportional representation of the data. Those nmi with nil value are represented by black disks.

As in previous surveys, blue whiting distribution is related to the continental shelf-break. In both surveys the external limit of the distribution seemed to be reached. There only were positives values at the end of two transects located in the northern part of the area of the second trip undertaken in 1994. Over the continental shelf, the inner limit appeared to be close to the slope. This was clearer during the trips performed in 1996 than in those carried out in 1994. Although there was a continuity between transects in North France during the 1994 survey, meaning that the inner limit was not yet reached, these values were, in general, lower and, therefore, we can assume that the limit was reached.

Within each area and trip there were a few samples with high values. These values had an important contribution on both arithmetical mean and variance. The global estimate and its precision are therefore determined by a few very large values (Petitgas, 1993). Whereas in South France and Spain there is no clear zonation of these high values, in North France during the second trip of the 1994 survey, they appeared to be concentrated on the northern part of this area. In order to apply the intrinsic theory, the assumption of no border effects was made, however.

Nevertheless, due to the skewness of the frequency distribution of the data, variograms were firstly performed on transformed data (logarithmic transformation). These variograms did not show clear anisotries and therefore isotropics variograms were constructed. Besides, these variograms were used to clarify the spatial structures found over raw data.

Figure 3 shows the isotropic experimental variograms for the raw data, rescaled to the variance value, for each zone and trip. Total number of data, total number of data inside each area of blue whiting distribution area and total of positives values, range, arithmetical mean (S_a), surface (nmi^2), fitted variogram models , c.v.'s and degree of coverage (Aglen 1982) for each zone and trip are shown in Table 2. Due to the low level of samples, those variograms corresponding to South France in 1996 were no constructed.

Between trips, they were important changes in the surface of the distribution area of blue whiting, which would probably be the most important fact. These differences are important in North France and in Spain, with changes of about the double of the total surface. In South France the area seems to remain almost the same. Changes during the survey carried out in 1994 were contrary to those found in 1996. Whereas in 1994 the surface increased up to the double in both areas, North France and Spain, from the first to the second trip, in 1996 there was a decreasing in the same way from the first to the second trip.

Mean S_a values seem to be stables when the surface of the distribution area change. In fact, these mean values were almost similar in North France in 1994. and with differences lower than 15% in Spain in both surveys. Only North France during 1996 showed changes in both mean value and surface. On the contrary, South France, which presented negligible differences in surface between trips, showed differences in mean values higher than 50%.

Spatial structures were performed using 1.5 nmi as a unit lag. Due to the narrower distribution of blue whiting around the slope and the distance between transects, these variograms show, in general, a low or even lack of pair values at certain lags. This feature could give spurious spatial structures. In order to avoid this problem, the experimental variograms were fitted to models using as a reference point those lags with a least of 30 pair of values. Variograms showed a spatial structure whose sills seem to be reached at 8-12 nmi. The fitted models were spherical and exponential and in some cases, the presence of a nugget effect was also observed. As a consequence of the different distance between transects in each survey, models constructed for 1994 fitted better than those constructed for 1996. Coefficient of variation in 1994 ranged from 10.74% to 26.65%. In 1996 the coefficient of variation varied from 15.11%

to 35.09%. Nevertheless the differences in variance of estimations agree with the differences in the survey design performed in each year. Besides, these differences agree with the differences in degree of coverage found in each area and year.

Back-scattering values were also analysed by means of the transitive theory. In 1994 an independence between transects with a fixed intertransect distance of 10 nmi was assumed. Cumulated transect values for each trip and year are plotted in Figure 4. As it was pointed out above, there were important differences between trips. In 1994 North France and Spain show an important increasing from the first to the second trip. In 1996 there was a general decreasing in the whole area from the first to the second trip.

Experimental covariograms and the fitted models constructed are shown in Figure 5. The number of transects, intertransect distances, range, and mean value of the cumulated values and the fitted covariogram models and their variance estimates and c.v.'s are shown in table 3.

Changes in mean values among trips and areas were clear. The most important changes which will be further reflected in changes in both number of fish and biomass occurred in North France and Spain.

Fitted models were no directly inferred from the variograms models fitted in 2-D. Nevertheless the fitted models were performed taking into account the spatial characteristics which were modelled in 2-D. The models seem to fit well with the experimental covariograms. It appears to be some inconsistencies between the estimated variances in 2-D and those estimated in 1-D in some areas and trips, however. These are also reflected in the coefficient of variation estimated for the two methods. The areas in which there were differences between c.v.'s, the estimations calculated by the transitive method (i.e. on covariograms models) were lower than those calculated by the intrinsic method (i.e. on variograms models). These differences will be discussed further.

The population structure found in 1994 was different to that found 1996. Age group 3 was the most abundant in 1994 whereas in 1996 age 1 and 2 represented up to 95 of the population. In 1994 it seems that the major change occurred in the total number of fish (Figure 6) remanding quite stable the age structure of the population from the first trip to the second in the different areas. In this year, the increase from the first to second trip was higher in Spain, where age group 3 became also more important. During 1996 there were important differences in both number of fish and age structure between trips. The decreasing in number of fish from the first to the second trip was also accompanied with a change in the population structure. This was so clear in North France with age group 2 and in Spain with age group 1. In North France age group 1 had a low increase from the first to the second trip whilst age group 2 decreased from 11 million fish to 3 million fish. In Spain age group 1 decreased from 52 million fish to 8 million fish; in this area the decrease of age group 2 was only about 0.7 million fish. The decrease of age group 2 in North France and age group 1 in Spain from the first to the second trip without an increase of these age groups during the second trip in others surveyed areas suggests that there was also movements outside the studied area.

Mean fish density expressed as a number of fish per square nmi in each area and trip is shown in Figure 7. In 1996 Spain shows high values of fish density compared to those estimated for the other areas and trips. Changes in fish density between trips were also detected in both surveys in Spain and in North France in 1996.

During the first trip of 1994, blue whiting was mainly distributed along the continental shelf-break; in addition in Spain it was also found on the continental shelf, close to the slope. Nevertheless this pattern of distribution was different in North France during the second trip of 1994 and in both trips of 1996. In these trips its distribution spreaded further offshore in a pelagic layer, around 150-250 m in 1994 and 250-350 m in both trips of 1996.

The mean length of blue whiting is described to be related to depth (Bailey, 1982). This seems to be true and the Kolmogorov-Smirnov test applied to the fishing stations performed in 1996 showed statistical differences among fishing stations. Nevertheless during the first trip of this survey a good correlation between mean length and depth appears to be found (coef. corr: 0.89, Figure 8) but during the second trip this relationship was no so clear (coef. corr.: 0.13).

In 1994 all the specimen were mature (Figure 9). During the first trip stage II (developing) was predominant, with a 89% in Spain; in addition in this area there was a 36% of specimen in stage VI (resting) and in North France the 30 % were in "active" stages, that this: stages III, VI and V (Prespawning, spawning and postspawning). During the second trip almost all the specimen were in stage VI. In 1996 an important part of the population were immature, being 71% in Spain during the first trip. The major part of the mature specimen were in stage V. During the second trip, this stage was also predominant in North and South France whereas in Spain, there was still an important proportion of immature specimen (47%), and stage VI represented 31%.

DISCUSSION

Since 1960, blue whiting has been known as an important migratory species in the North Atlantic (Bailey, 1982). While in summer and autumn the species is widely dispersed over most of the Norwegian Sea, important concentrations of blue whiting begin to form at the end of the year. By February, beginning of March adult fish are concentrated around Porcupine Bank where they spawn. After the spawning season there is an exodus from this area. From the North this movement is well documented. Monstad and Belikov (1993) found an important rate of migration, and this main spawning area became almost empty at the beginning of April which it is one month later after the peak spawning. Nevertheless, these surveys never reach waters further south than 49° N, so the possibility of migration southwards was unknown.

From this study, quick changes in both number of fish and population structure of blue whiting appears to be clear. In 1994 the age structure found and the differences in maturity stages together with the changes in fish abundance, could indicate a southward movement after the spawning season from the main spawning ground. Nevertheless this movement of adult fish is scarce in comparison to that undertaken northward.

On the other hand results from 1996 were different from those of 1994. Juvenile fish (age groups I and II) were predominant and there was an important decrease from the first to the second trip. The main changes in terms of number of fish occurred in North France related to age group II and in Spain related to age group I. Both age groups seems to be disappeared from the studied area. Besides, this age groups have an important proportion of immature fish (82% and 52% from the maturity ogive, Anon, 1996) which would not make this spawning migration. This also agrees with the low number of fish in stage VI (spent) found in both trips. Concerning to fish older than two years, there was a decrease in North France from the first to the second trip whereas in Spain there was an slight increase. In addition, this year the peak of the spawning was earlier and the postspwaning migration might be take earlier than usual (Monstad *et al*, 1996). The most noticeable feature are the quick changes in both age structure and number of fish in a relatively sort periods of time.

Changes in fish abundance in North France and South France seems to be related to an increasing in the distribution area rather than a change in fish density expressed as a number of fish nmi^{-2}. In 1994 whilst the total number of fish increased twice, there was no changes in fish density between trips. In 1996 in North France there was also a decreasing from the first to the second trip. In Spain the changes in fish density were more important in both surveys, being higher than a 200%. The great values found in 1996 seems to be related to the presence of young fish. At least in the studied area, blue whiting appears to be associated to the continental shelf-break. Once the number of fish is increasing, the distribution area is spreaded. In France the area is extending to deeper waters, in a pelagic layer at around 200-300 m, with almost no presence on the shelf. In Spanish wasters, as well as in France, it is mainly distributed on the slope, but it extends its distribution area through the continental shelf until 100-150 m., with almost no extension in a pelagic layer like that found in France. The Spanish shelf is narrower than the French shelf, but it is also deeper, going down as far as 250 m in comparison to the 150 m of the French. This topographical difference may explain the presence of blue whiting over the Spanish shelf, but it would not explain its lack of extension in a pelagic layer like that in French waters. According to Porterio *et al* (1996) the different hydrodynamic activity could explain this different behaviour of blue whiting.

From the analysis of the previous surveys (spring 1991-1993), the range of the spatial distribution of the variograms of blue whiting is found to be 10-15 nmi. These values agree with those found during these surveys. The variograms models performed in 1994 cruise gave good fitting to the experimental ones. Due to the lack of pairs at certain lags, variograms from South France and Spain showed some problem to be fitted. In addition, these two models gave a coefficient of variation higher than the others. The same problem about the lack of pair values at certain lags in the variograms arose in the second trip of 1996. The models in this trip were fitted with ranges of about 8-12 nmi, in which the range of the spatial structures is expected to be found. Since models performed in 1994 during the second trip and in 1996 during the first one had range around 8-12 nmi, fitted models with this range performed for the first trip of 1996 might be appropriates.

Experimental covariograms were fitted with regarding to the spatial found in the variograms. Covariograms of South France in 1994 only had 6 transects. In addition cumulated values were similar, specially during the second trip. Both features might contribute to the apparently continuity that spatial structures present. Whereas the spatial structures of blue whiting have a range about 10 nmi, the distance between transects during the 1996 cruise was 24 nmi. If any spatial structure existed at lower distances than 24 nmi, it would be mask, and therefore, any estimation of the variance based on this model could be biased.

The narrower distribution of blue whiting in certain areas of the different trips and the low level of sampling inside these areas, in both number of transects and number of nmi steamed, could lead to spurious spatial structures in both covariograms and variograms and hence the differences in coefficient of variation calculated by intrinsic and transitive methods could be explained.

Nevertheless, in order to obtain abundance estimates with a reasonable good precision and at least from this area, a survey design with a distance between transects of 10-12 nmi would be appropriate.

In spite that important blue whiting movements around the Bay of Biscay have been detected, the relation with a postspawning migration is scarce. It seems that the southward postspawning migration from the Porcupine is undertaken for a few young mature specimen (mainly age groups II and III). But this migration is sparse compared to that undertaken northward (Monstad *et al*, 1996).

In addition the Spanish monthly catches of blue whiting remain stables throughout the year and the total yearly catches appear to be also stables at around 32 thousand tonnes since 1981 (Anon, 1996). The fisheries are mainly developed on young fish (age groups 0, I and II) and the age structure remains also throughout the year. The same age structure is also found in the acoustic surveys carried out in spring and in the bottom trawl surveys carried out in fall.

In absence of adult fish as well as the lack of significant spawning grounds in this area (Porteiro *et al*, 1996), a young migration or a southward larvae drift (Fraser, 1958) could be suggested. The presence of juveniles in this area has been reported (Maucorps, 1979) and has also detected during these surveys (Carrera *et al*, 1996). There is, however, some evidences about a differential pattern of distribution of blue whiting. During the spawning season (spring) the length distribution in Porcupine Bank normally ranged from 19 to 40 cm (Monstad and Belikov 1993), with 28 cm as mean and a unimodal length frequency distribution. During the feeding season (summer) in the Norwegian sea, the length distribution can present different modes, corresponding to the O group and the others at lengths between 22-28 cm (Jacobsen, 1990a-b, 1991, Monstad and Dommasnes, 1990 and Monstad, 1990, 1993). There is, however, a discontinuity between these, corresponding to length group from 16 to 22 cm, which are the main length groups found in both the Spanish and Portuguese fisheries and in the acoustic surveys in Spain (Meixide et al 1991, Anon 1993a). Also in catches further north than 50° N the length groups between 16 to 22 cm are relatively scarce which is in agreement with this theory. This kind of behaviour can be seen in other species such as horse mackerel, which presents a poor distribution of specimens between 19 to 22 cm length classes in the Spanish fisheries, in coincidence with the first sexual maturity (Abaunza et al. 1995).

According to that, it could be better to emphasise the presence of a nursery area in this area as a result of a drifting processes together with a juvenile migration rather than an adult postspawning migration. To demonstrate this, more information is needed and further surveys should be carried out in summer when the juvenile are fully recruited.

Acknowledgements

We are indebted to the staff who took part in the SEFOS 0394 cruise. Also our acknowledgements to the crew of the R/V "Cornide de Saavedra". We wish also to thank John Simmonds and Dave Reid who helped us to design this survey and to the anonymous referees who helped improve a first draft presented at the Fisheries and Plankton Acoustics Symposium held in Aberdeen in June 1995. This study was developed under the frame of the EU-AIR, SEFOS programme (AIR2-CT93-1105).

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Survey	Trip	Date	Design	No Transect	Fishing st	CTD st
SEFOS 0394	First (ft)	19/03-14/04	zigzag	34	10	80
	Second (st)	19-25/04	20 nmi apart	34	9	-
SEFOS 0396	First (ft)	21-29/03	Parallel	22	12	78
	Second (st)	7-13/04	20 nmi apart	22	9	-

Table 1: Main features of the cruises

Area	Trip	No	No Inside	Range	Mean	Area	Variogram model	var est	c.v.	d.c.
North France	1994 ft	307	102(94)	0-7400	895.04	926.74	Exp(1.22E+6; 10)	21796.25	16.49	3.35
	1994 st	325	223(220)	0-16000	909.96	2012.21	1.75E+5 + Exp(1.9E+6; 12)	18916.38	15.11	4.97
	1996 ft	345	166(135)	0-7000	741.87	4052.55	Exp(1.59E+6; 8)	26114.88	21.78	2.61
	1996 st	315	101(91)	0-4000	422.97	2377.75	2.0e+5 + Sph(1.9E+5; 12)	7750.12	20.81	2.07
South France	1994 ft	123	56(55)	0-4000	644.11	553.41	1.0E+5 + Exp(6.3E+5;10)	29454.84	26.65	2.38
	1994 st	127	62(61)	0-1600	334.92	511.73	1.0E+4 + Exp(8.9E+4; 12)	2963.44	16.25	2.74
	1996 ft	58	10(9)	0-3700	880.00	151.00	n.a.	n.a.	n.a.	0.81
	1996 st	58	8(7)	0-600	312.50	148.76	n.a.	n.a.	n.a.	0.66
Spain	1994 ft	381	68(66)	0-2500	344.28	657.90	Exp(1.53E+5; 10)	4322.06	19.10	2.57
	1994 st	310	141(136)	0-2000	415.50	1207.44	1.0E+4 + Exp(1.39E+5; 8)	1990.55	10.74	4.06
	1996 ft	237	99(89)	0-3800	606.16	2608.79	Sph(7.84E+5; 12)	23255.50	25.16	2.04
	1996 st	207	65(61)	0-10000	606.92	1361.70	8.0E+5 + Sph(8.3E+5; 12)	45348.69	35.09	2.09

Table 2: Estimates of relative abundance using the intrinsic theory splited by area and. trip. Ft and st means first trip and second trip respectively. Number of data for the total area, number of data inside the delimited area of blue whitng distribution with number of positive values in brackets, range and mean value (S_a values) and area (surface expressed as nmi^2) of the delimited area, fitted variogram model and its variance estimate and coefficient of variation and the degree of coverage (No data inside area/square root of the area)

Area	Trip	No	Distance	Range	Mean	Covariogram model	var est
North France	1994 ft	11	10	300-29550	8299.45	Sph(8.4E+9; 10)+Sph(7.58E+9;110)	2.27E+10
	1994 st	11	10	550-67550	18447.27	Sph(4.13E+10; 12)+Sph(3.6E+10; 110)	8.20E+10
	1996 ft	12	24	600-23949	10262.42	Sph(5E+9; 8)+Sph(1.69E+10;110)+Sph(2.4E+10; 288)	1.25E+1[illegible]
	1996 st	12	24	400-8050	3564.17	Sph(1.05E+9; 12)+Sph(4.4.5E+9;288)	1.80E+10
South France	1994 ft	6	10	1190-9050	6011.67	Sph(1.0E+8; 10)+Sph(2.6E+9; 60)	1.33E+09
	1994 st	6	10	2610-4375	3460.83	Sph(1.0E+7; 12)+Tri(7.3E+8;60)	2.21E+08
	1996 ft	2	24	2100-6700	4400.00	n.a.	n.a.
	1996 st	2	24	1000-1500	1250.00	n.a.	n.a.
Spain	1994 ft	17	10	10-5040	1377.12	Sph(2.6E+8; 10)+Sph(3.1E+8; 170)	6.96E+08
	1994 st	17	10	50-6880	3450.88	Sph(6.5E+8; 8)+Sph(2.25E+9;170)	2.93E+09
	1996 ft	8	24	800-22870	7501.25	Sph(5.3E+9; 12)+Sph(8E+9;48)+Sph(1.0E+10; 192)	1.11E+11
	1996 st	8	24	1000-16650	4943.75	Sph(4.0E+9; 12)+Sph(2.7E+9;48)+Sph(2.2E+9; 192)	6.97E+10

Table 3: Estimates of relative abundance using the transitive theory splited by area and. trip. Ft and st means first trip and second trip respectively. Number of transects per area,distance between transects (nmi), range and mean value (S_a values), fitted covariogram model and its variance estimate and coefficient of variation.

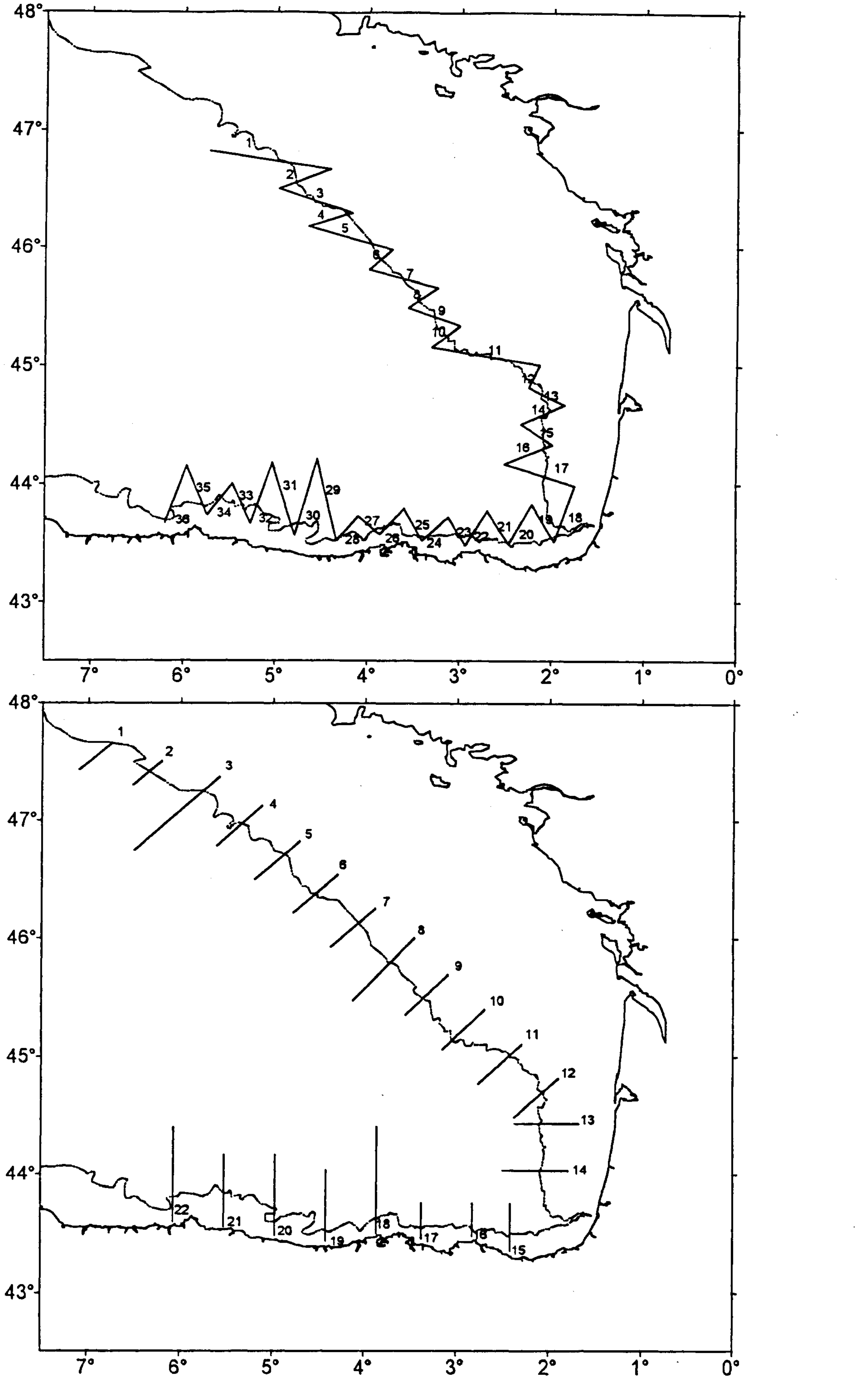
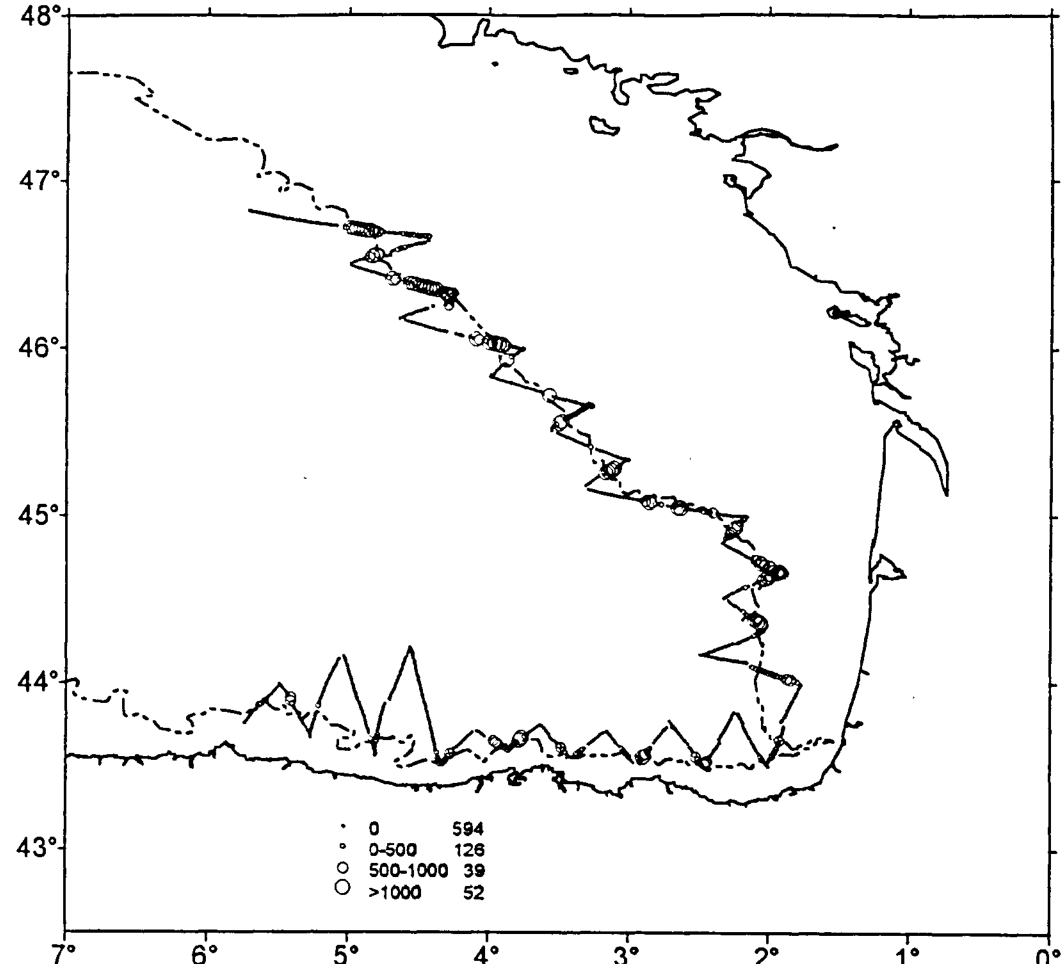


Figure 1: Acoustic tracks in SEFOS 0394 (above) and in SEFOS 0396 (below)



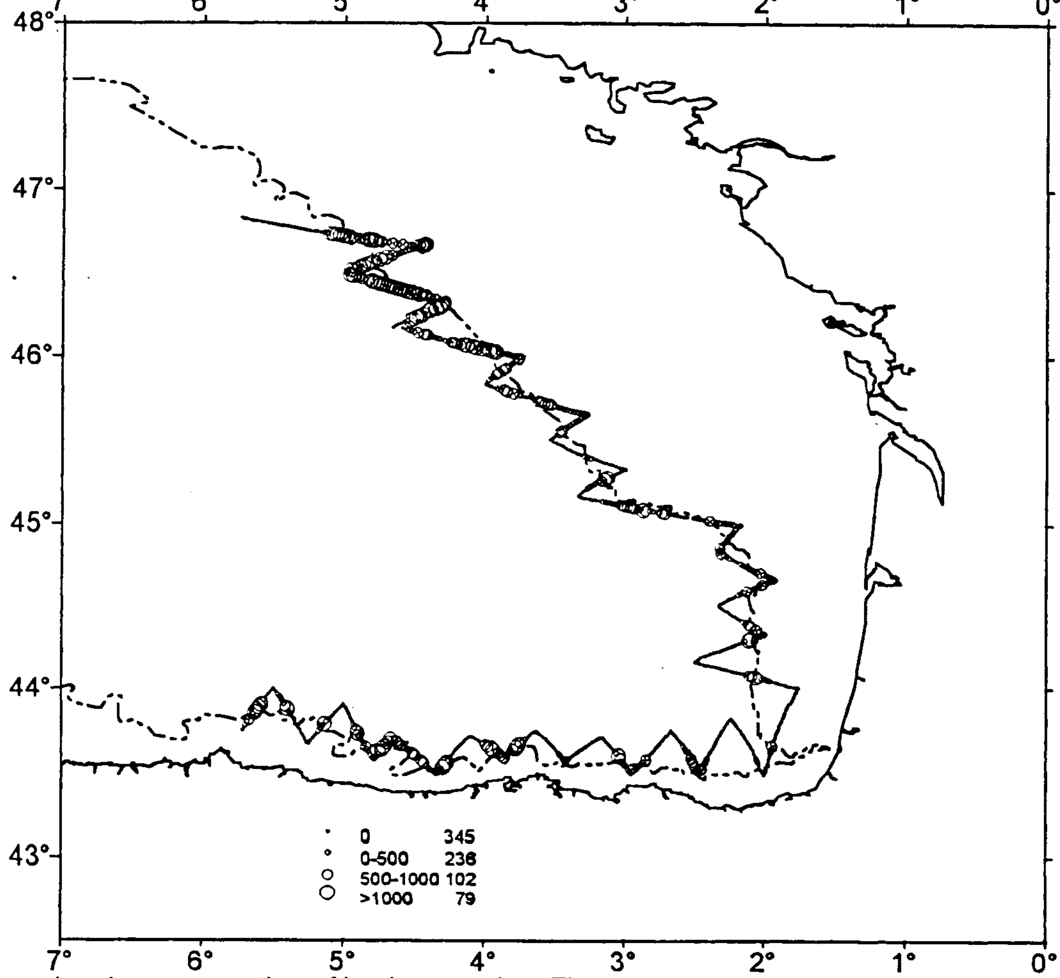


Figure 2a: Proportional representation of back-scattering. The zeroes are denoted by blak disks. Above SEFOS 0394 first coverage and below SEFOS 0394 second coverage

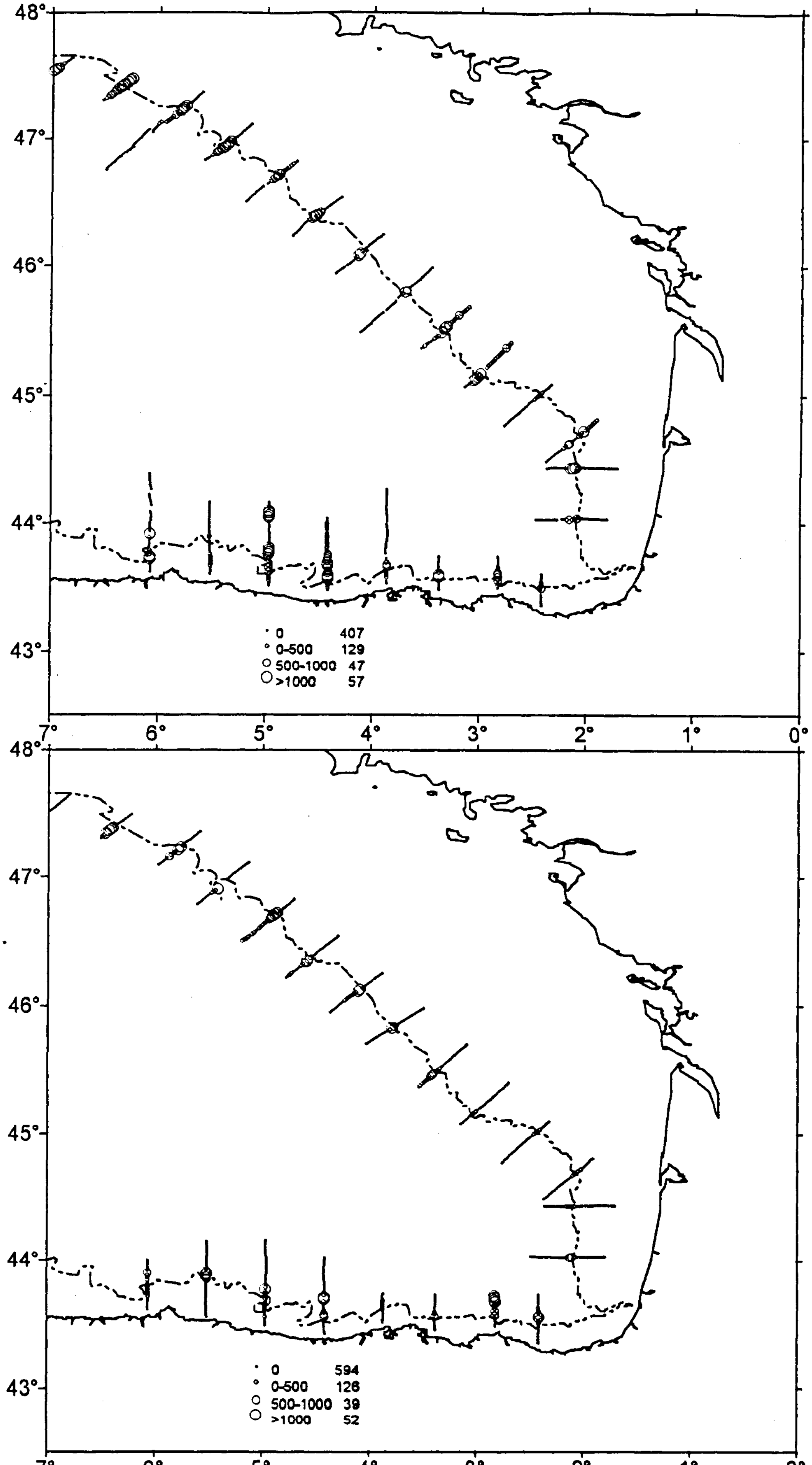


Figure 2b: Proportional representation of back-scattering. The zeroes are denoted by blak disks. Above SEFOS 0396 first coverage and below SEFOS 0396 second coverage

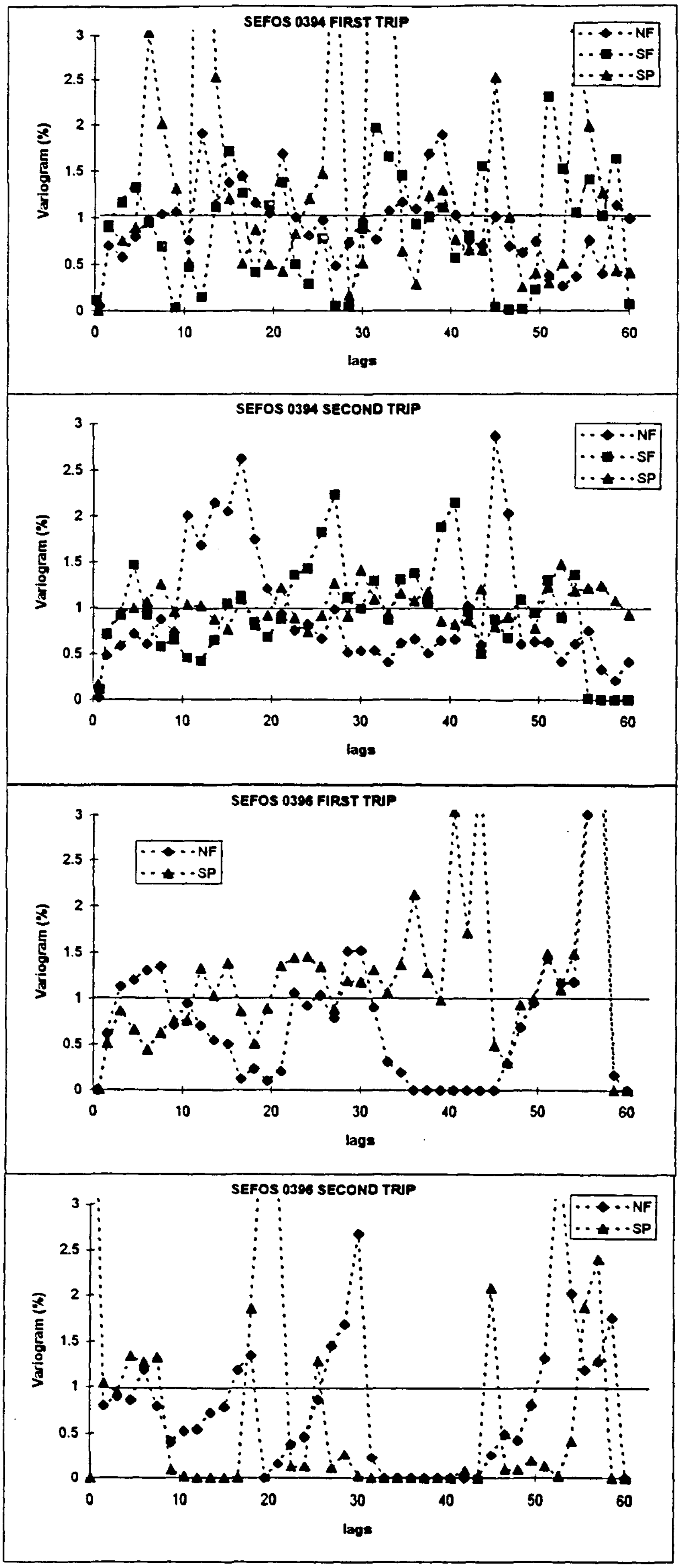
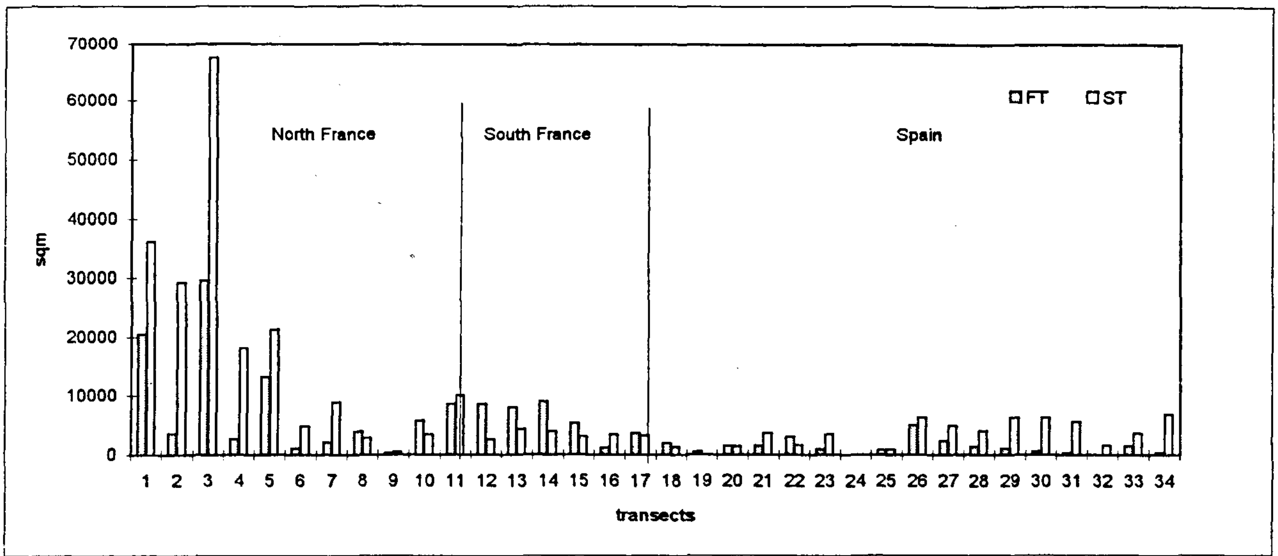


Figure 3: Experimental variograms of the raw data. Semivariance values are rescaled to the variance



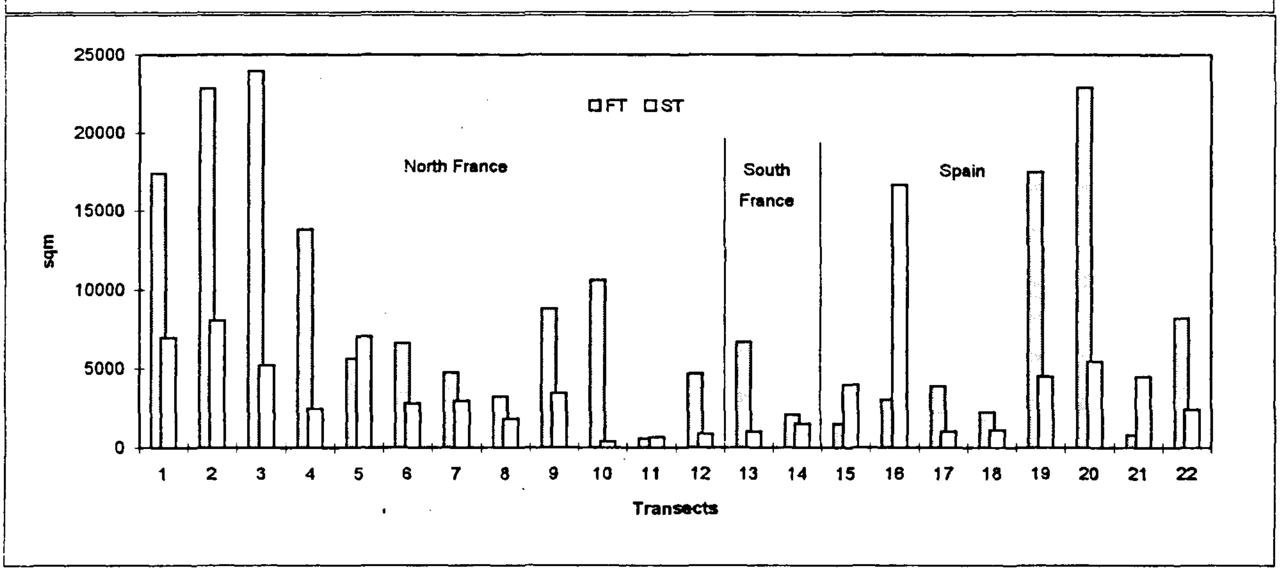


Figure 4: Cumulated fish back-scattering values along transects. Above SEFOS 0394 and below SEFOS 0396. FT and ST mean first trip and second trip respectively

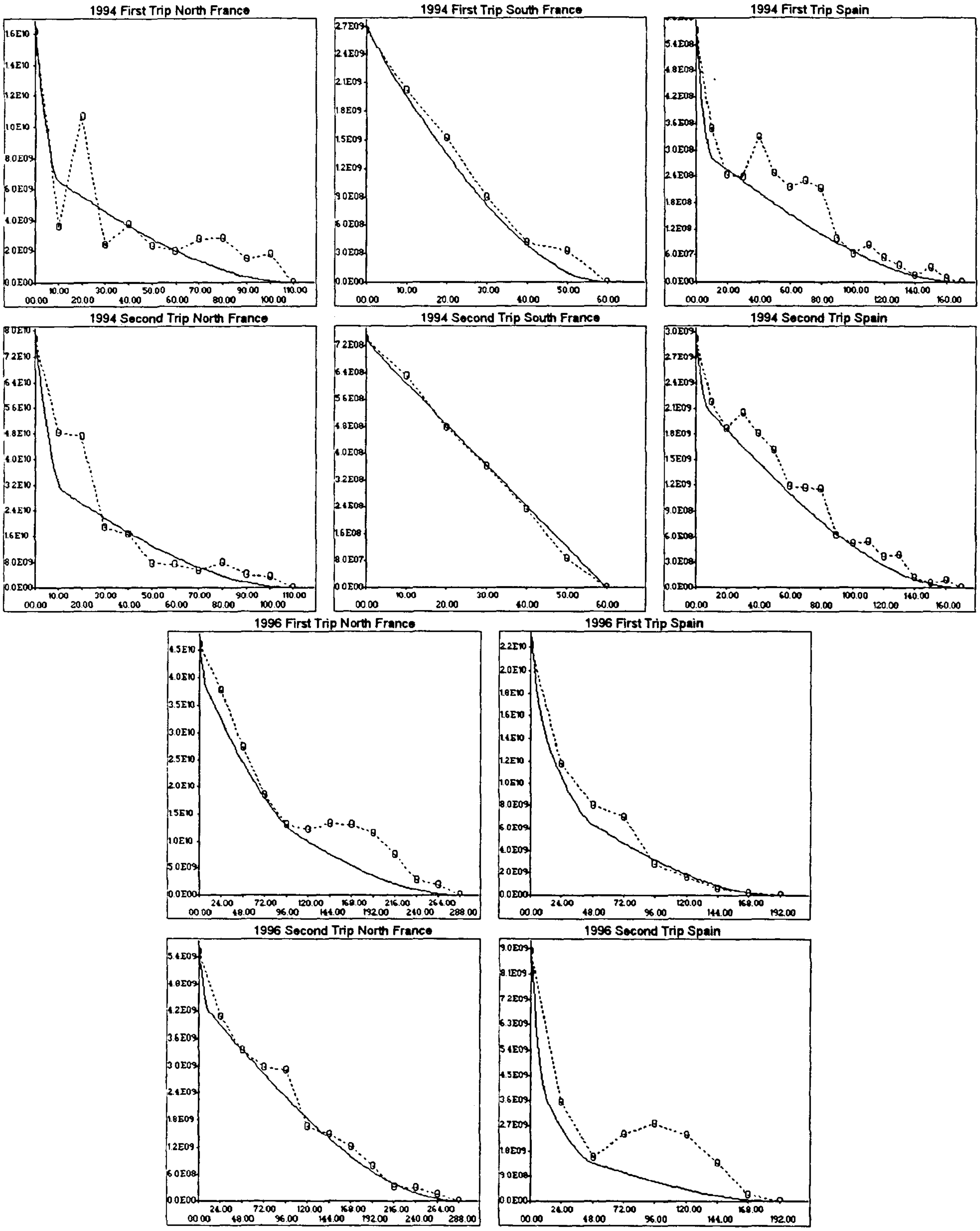


Figure 5: Experimental covariograms of the raw data and fitted models for each area and trip.

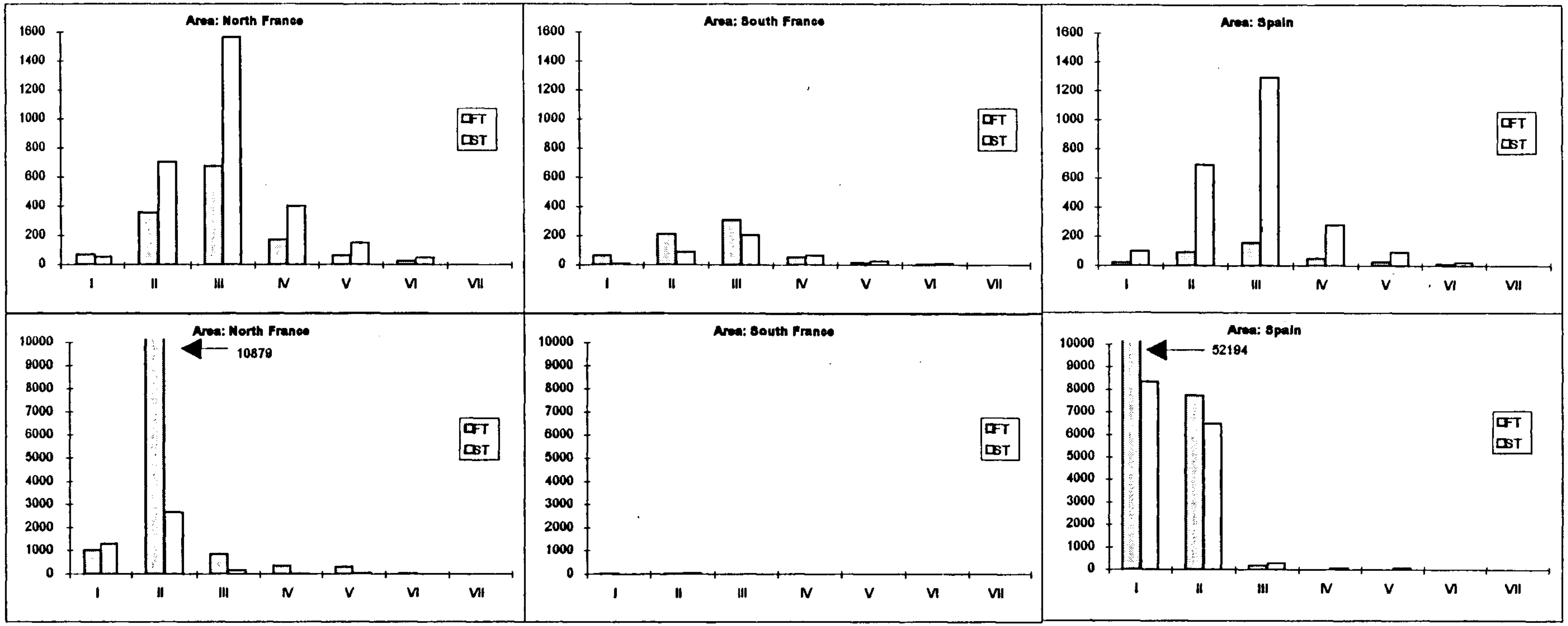


Figure 6: Number of fish (millions) by age group for each trip and area. (FT and ST mean first trip and second trip respectively.

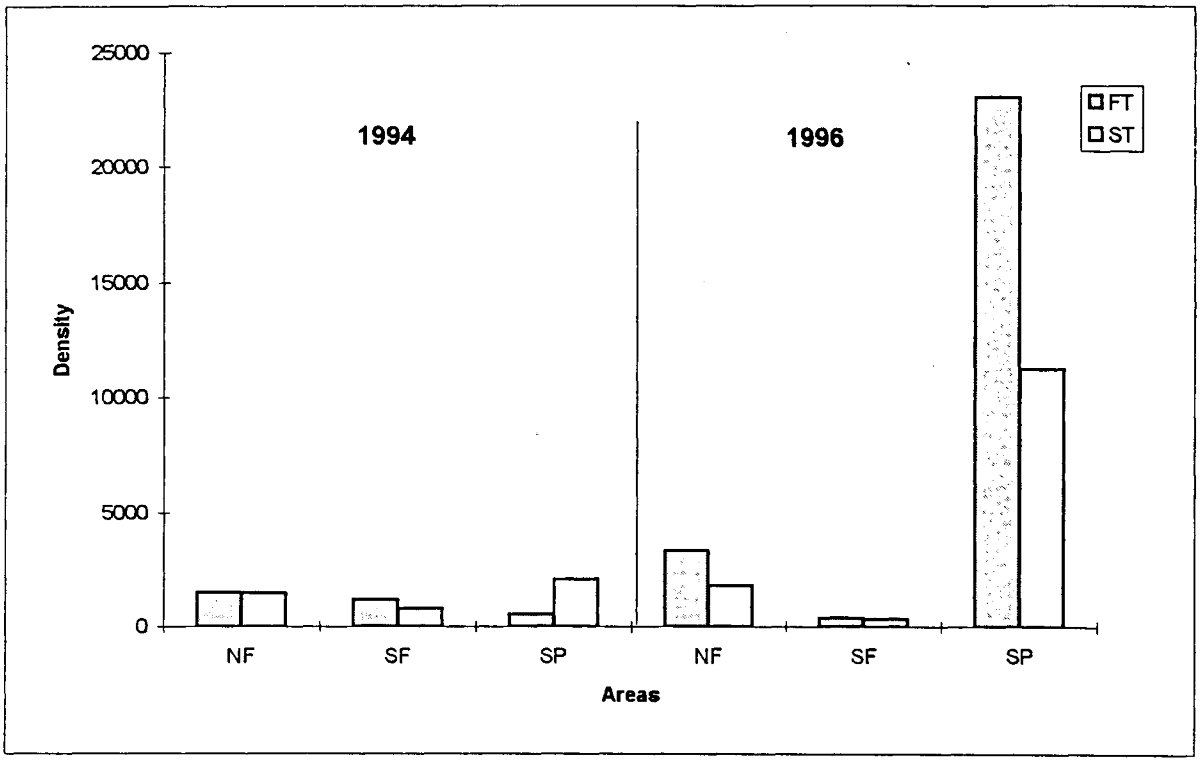


Figure 7: Mean density (Million fish by squere nmi) for each area and trip

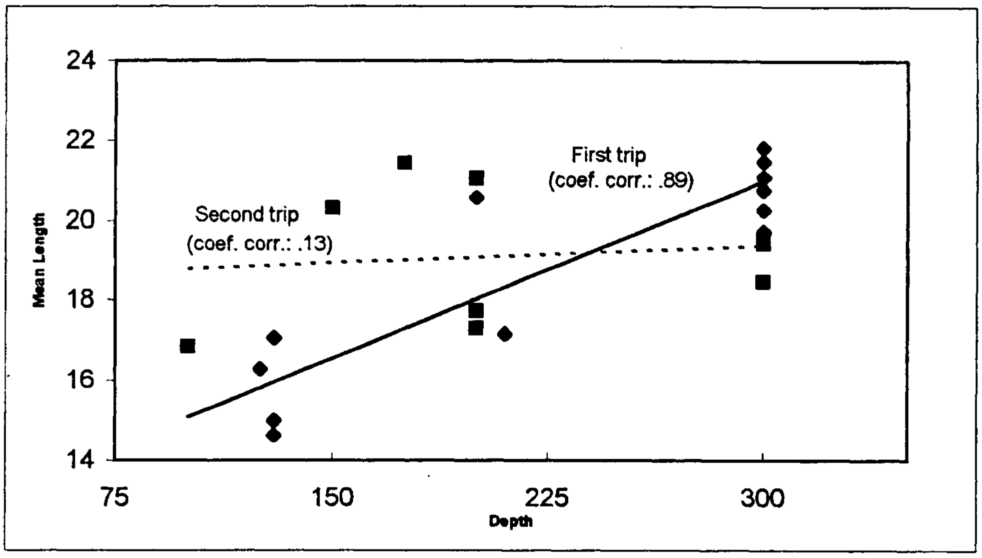


Figure 8: Mean length/Depth relationship during SEFOS 0396 survey

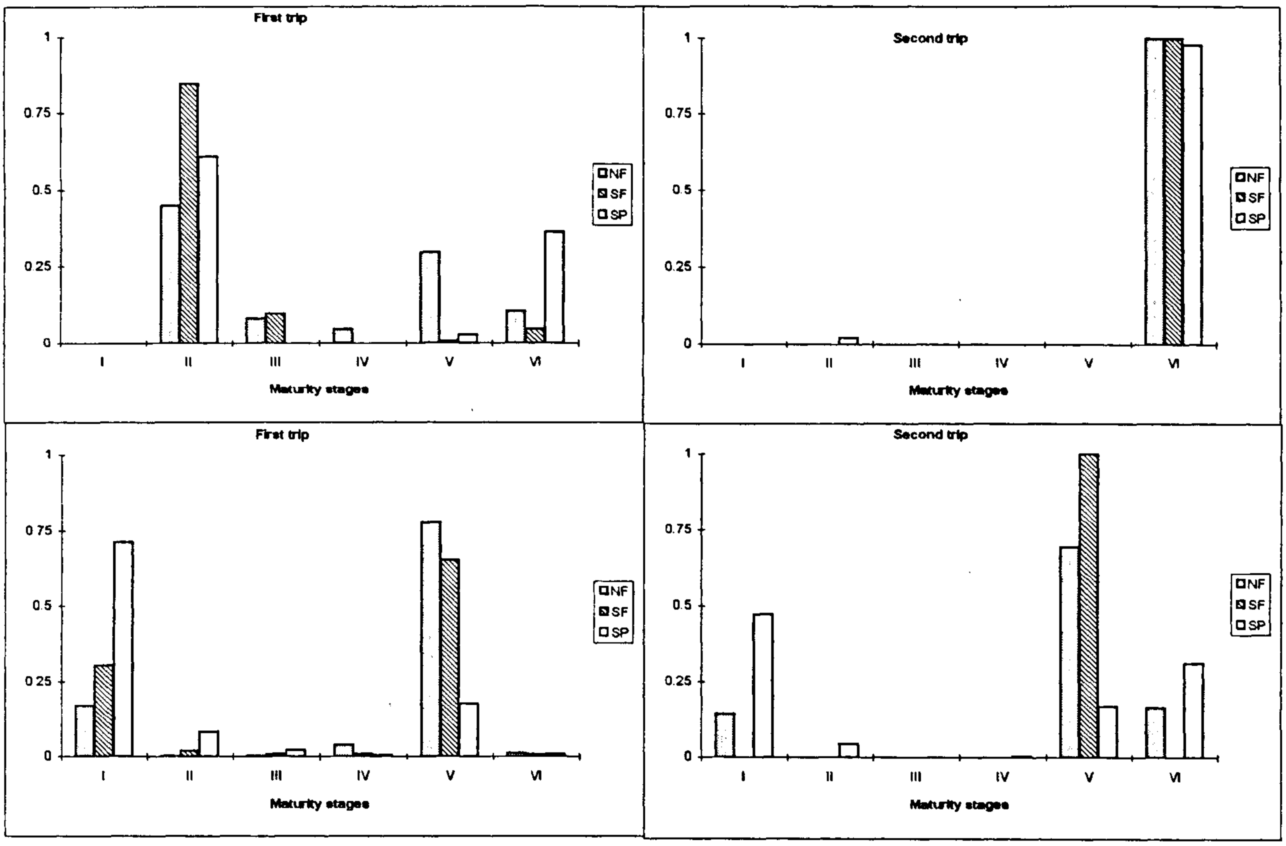


Figure 9: Maturity stages for each area and trip. Above 1994, below 1996. NF, SF and SP mean North Frane, South France and Spain respectively